Air conditioning as a risk for increased use of health services

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Background

Occupants of office buildings with air conditioning (AC) systems (e.g. central ventilation with cooling of air) consistently report, on average, more symptoms in their buildings than do occupants of buildings with natural ventilation. This has been the finding in individual studies from many studies over the last 20 years, and in three reviews.1–3 The symptoms in these studies have included mucous membrane irritation, breathing difficulties, irritated skin, and constitutional/neurological symptoms such as headache and fatigue. This set of non-specific symptoms, often referred to as building-related symptoms or sick building syndrome, has not been linked to specific known diseases. The association of AC with increased symptoms has received little recognition outside the world of indoor environmental research. This may be because the health outcomes studied have been subjectively assessed and limited to acute, non-specific symptoms, and because specific environmental exposures have still not been clearly implicated as the causal factors.

Available evidence, although not conclusive, suggests that this pattern is not due to an association of AC systems to either less outdoor air ventilation, poorer thermal control, or lack of openable windows.3 An explanation is that ventilation systems in buildings, especially those with AC systems or humidification systems, disseminate contaminants into the indoor air. What these contaminants might be, and through what biological response mechanisms they cause a constellation of non-specific symptoms, is not yet clear.

A more likely explanation is that the moisture in AC and humidification systems results in microbiological exposures that cause health effects through mechanisms that are irritant, toxic, or allergic. Very substantial evidence now exists that the presence of visible moisture and mould in many kinds of buildings (associated with condensation, leaks, floods, or other moisture incursions into the interior or envelopes of buildings) is consistently associated with increased risk of respiratory symptoms and asthma.4–7 It is only recently, however, that researchers have linked specific metrics of exposure to microbiological materials of various kinds in indoor air and dust (e.g. endotoxin8 and beta-1–3-glucans9,,10) with increased health risks; the metrics used historically for measuring exposures to airborne culturable micro-organisms have not generally correlated with health risks indoors.

Furthermore, surfaces in AC systems that remain constantly moist, such as the cooling coils and drip pans, are supportive environments for the growth of undesirable micro-organisms, are directly in the path of all air supplied to occupants to breathe, and are often not well-maintained. However, surprisingly little research attention has been focused on this potentially troubling issue: only a few studies have assessed links between moisture in ventilation systems and health effects among occupants.11,,12 Multiple associations were found, including a reported odds ratio (OR) of 4.8 (95% CI: 2.0, 12) for increased wheeze, shortness of breath, and cough in relation to an index of moisture in the ventilation system.11

Recently, however, Menzies13 reported startling findings from a blinded, controlled study testing ultraviolet (UV) irradiation of cooling coils and drain pans in AC systems of office buildings without known building-related health problems. The study found substantially reduced symptoms during UV radiation, especially among atopics and non-smokers. The UV condition reduced lower respiratory symptoms by 30% among current smokers but by 60% among never-smokers. The findings suggest that micro-organisms growing on moist surfaces in typical commercial AC systems may cause substantial increases in building-related symptoms. The findings also imply increased responsiveness among atopics and non-smokers to these microbiological exposures, presenting as increased respiratory and musculoskeletal symptoms. Such a pattern suggests hypersensitivity pneumonitis, a rare and potentially serious immunologically mediated disease with a similar pattern, as a biological model for this apparently more common and less severe health effect. Hypersensitivity pneumonitis-like illness caused by indoor work environments has been documented repeatedly,14–17 generally related to leaks, but is considered rare.

The literature on non-specific building-related symptoms in offices, consistently linked with certain types of ventilation systems, has assumed that these symptoms cause some discomfort and reduced work efficiency but resolve away from the buildings. The literature on visible moisture and mould in buildings suggests immunological responses such as asthma or allergies, involving either triggering or initial sensitization.4–7 The findings of Menzies,13 in turn, suggest that contaminants from AC systems in commercial buildings may cause an immunologically mediated response in a substantial proportion of occupants. A number of studies also suggest that buildings with inadequate ventilation may increase the transmission of infectious respiratory diseases among occupants,18,,19 although this link has not been well-documented. Anecdotal reports to investigators of 'problem' office buildings often mention frequent infectious respiratory illness or sinus infections that do not resolve away from the building. These complaints may be related to results of inadequate ventilation or, if moisture is present, to the increased susceptibility to respiratory infections documented in relationship to damp or mouldy buildings.20,,21 Overall, the scientific literature suggests that building-related health effects in offices, including allergic, asthmatic, and infectious mechanisms, are in fact not all minor and transitory. Effects of building environments on utilization of health care are thus plausible, but have not been previously assessed.

Summary of study findings

In this issue of the journal, Preziosi et al.22 report the first study to assess differences in the utilization of health care related to the presence of AC in office workplaces. Although the study was simple and cross-sectional, the data variables from questionnaires, and the findings subject to a variety of questions, the findings are striking enough to deserve clarification. The study used a large random national sample of French women assembled for another purpose (to study antioxidant nutrients and prevention of cancer and cardiovascular disease). Participants reported health services and health events in monthly questionnaires over one year, and in one questionnaire in the middle of that period also reported whether AC was in use at their workplace. Fifteen per cent of participants reported AC at work. Analyses adjusting for age and smoking status of participants found increases in most outcomes assessed: use of specific kinds of physicians, sickness absence, and hospital stays. While the increases in OR and 95% CI were statistically significant for only otorhinolaryngology (OR = 2.33, 95% CI: 1.35, 4.04) and sickness absence (OR = 1.70, 95% CI: 1.13, 2.58), other increases were notable—dermatology (OR = 1.6, 95% CI: 0.98, 2.65); hospital stay (OR = 1.51, 95% CI: 0.92, 2.45), and pneumonology (OR = 2.10, 95% CI: 0.65,

6.82). The least elevated outcomes were for general practice medicine (OR = 0.99, 95% CI: 0.65, 1.48) and global medical visits (OR = 1.18, 95% CI: 0.67, 2.07) (ref. 22, Table 2).

OR for relatively common health outcomes often lie farther from the null than the risk ratios most useful for quantifying the increase in risk. Risk ratios, or prevalence ratios (PR, the equivalent measure of effect for cross-sectional data), have seldom been used because of the convenience and availability of logistic regression models that estimate OR. With baseline prevalences ranging up to 85.7% in the data from Preziosi et al.,22 PR allow a more appropriate estimate of the increase in each outcome associated with the risk factor of AC. The increase in prevalence was roughly estimated as (100* [crude PR * adjusted OR/crude OR] − 100) %. Based on the data in Table 2 of Preziosi et al.,22 estimates for the increased prevalence associated with air-conditioned offices include increases of 120% in otorhinolaryngology visits, and 40% in sickness absence. If these associated increases represented valid causal relationships, it would indicate enormous costs for employers and for society associated with AC systems, from increased health care and for reduced workplace productivity from sickness absence, in addition to a large burden of disease on workers.

Commentary

These findings are noteworthy, considering that such relationships have not been noticed among the large number of people working in air-conditioned buildings for decades around the world. While these increases are of similar magnitudes to the increases in symptom prevalence associated with AC in many prior studies, they are surprisingly large increases for health outcomes sufficiently serious to motivate visits to specialist physicians. The relatively large increases in sickness absence and especially hospital stays are even more surprising. Furthermore, it is odd that AC, given its other associations, was not associated with any increase in general medical practice. What evidence is there that these surprising findings are internally valid? The authors describe as a limitation of the study its focus on women within a narrow age range only; however, while this may limit generalization to other populations, these study features potentially strengthen the internal validity of the findings by eliminating sources of confounding.

Chance seems unlikely to explain these findings, as six of eight estimates exceeded 1.0, including P-values of 0.002, 0.01, 0.06, 0.06, 0.10, and 0.11 (ref. 22, Table 2). The P-values for ‘General Practice’ and ‘All’ medical attendance, however, do seem uncharacteristically low for the OR and CI reported.

What types of bias could explain such findings if the underlying relationship found did not exist or was much smaller? Selection bias seems unlikely in this large random national sample. Regarding confounding—individuals of higher socio-economic level may be more likely to have air-conditioned work settings, to be able to afford specialized health care, and to seek specialized health care, and warmer regions with more air-conditioned offices may have different patterns of disease or health care utilitization. Yet these are unlikely to be important confounders because: (1) the populations with and without AC at work did not differ markedly on the demographic variables reported; (2) the statistical models used adjusted for age and smoking status, and the authors report that adjustment of analyses for other potential confounders such as occupation or geographical region did not modify the findings; and (3) nationalized health care in France should equalize access to health care across income levels. The role of residual confounding by these factors is impossible to quantify from this very brief report. It is not clear what other demographic factors likely to be associated with air-conditioned workplaces in France could create substantial confounding.

Reporting bias could artificially create the relationships seen, either by those in air-conditioned buildings reporting or seeking more doctor visits due to concern about health effects of AC, along with the reverse behaviours in those without AC, or by similarly biased reporting of ventilation type by those with and without doctors' visits. The authors, however, report that health effects of AC is not a current issue in France, and that the study was unlikely to have created it as an issue in the minds of participants: the question was not mentioned as a topic within the study on nutrients, cancer, and cardiovascular disease, and the AC question was asked just once, after half of the health data had already been collected.

Considering the complexity of ventilation systems and the categorization of ventilation systems by the building occupants using non-technical language, it seems likely that much non-differential (essentially random) misclassification of buildings by ventilation type occurred in this study. This would tend to bias resulting in estimates toward showing no relationship. Some of the earliest studies of ventilation type and symptoms, for example, categorized buildings as air-conditioned that in fact had central ventilation systems with no cooling. Risks related to AC were inconsistent across these earlier studies. Once standardized categories were created1 (such as AC, and mechanically ventilated without AC), the presence of AC systems in office buildings became and has remained entirely consistent as a risk factor for increased building-related symptoms across all reported studies.1,3,23,,24

The study and analysis reported by Preziosi et al.22 were simple and limited but without obvious major errors. The findings suggest that health effects related to AC systems in offices are more severe than prior research has documented or even considered. The sizes of the increased risks reported, especially for sickness absence and hospital stays, are large.

If these findings were internally valid, it is not clear what known mechanisms could explain them. Minor irritant symptoms disappearing when away from work would not lead to the reported increases in doctor visits, illness absence, and hospitalizations. More persistent or chronic effects such as asthmatic sensitization or exacerbation, chronic sinusitis, or even some variant of hypersensitivity pneumonitis would seem to be required. Increased respiratory infections are another possibility. Increases in illness of an amount consistent with these findings have not been documented previously; yet, they have not been expected or sought in scientific studies. In fact, the first finding that symptoms were increased in air-conditioned buildings, and very common even in buildings without known prior health complaints, was a serendipitous discovery of a survey of hypersensitivity pneumonitis-related symptoms in office buildings.25

Clearly the results of Preziosi et al.22 are surprising and inconsistent with what would be expected, not so much for finding any increased risks but for the size of the risks found. The findings, if valid for large populations, would indicate large social costs and a common burden of individual disease related to current AC systems. While it seems most likely that some process of reporting bias or confounding has enhanced the risks found, this study clearly needs to be replicated in different populations of people and buildings. Replication should not be difficult, but it should involve improved data on risks and potential confounding factors, and explicit control for these factors in the design or analysis. Future studies should also assess likely environmental causes, to the extent current measurement technologies allow. One powerful study strategy would be controlled preventive intervention trials that reversibly remove

hypothesized contaminants before they reach occupants, using technologies such as UV13 or filtration within ventilation systems to study causation and prevention simultaneously.

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